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Booster Experiment - Preliminary Report of Multiturn Studies on February 2, 1974

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Recent measurements and operating experience have indicated that multiturn injection is not as efficient as the best achieved. The apparent septum thickness is usually several millimeters (whereas the physical septum thickness is $\approx .1$ mm). This effect has frustrated attempts to improve overall beam quality by better emittance matching of the injected beam. Accordingly, measurements were made of beam position and angle at the injection girder.

Experiment

The horizontal tune was moved to .667 for convenience of injection angle measurement. Measurements were made at three times; one at the peak of S1 and S2 pulses and one each at +5 and -5μS from center.

Time (from S1 center)	Angle
-5	negative, septum thin
0	≈ 0
+5	negative

The center of the S1 and S2 pulses were moved to the early time. The injection angle was near zero and the septum still appeared thin. However, when the linac beam time was moved 5 μ sec earlier, the septum appeared thicker and the injection angle remained the same. Apparently a position shift occurs during the linac pulse.

We then arranged to move together the wire 9 sample time, the trigger times of S1, S2, and the chopper trigger times. This allows us to make beam position measurements at different times in the linac pulse, having removed the transient effects of the pulsed elements in the 200 MeV line. The wire 9 sample time was derived from a booster trigger (TG) so as not to change the sample time TDATA) used to take data for linac rf regulation. The center position of the injected beam on wire 9 was recorded. The beam center was found to move away from booster center approximately 1.9mm during the above 10μ sec period.

A measurement of linac momentum shift during the same time interval was made with the spectrometer. This gave a shift of $\approx -.06\%$ (≈ 2.8mm where 1mm is $2.1 \times 10^4 \Delta p/p$). The 200 MeV transport quad currents were recorded for later reference. There was not sufficient study time to measure the change in injected beam angle during the 10 μ sec (it is, however, expected to be small). The position of the beam in both planes at the exit from the linac was measured and showed essentially no shift during the 10 μs interval.

In order to relate the beam position shift to the linac momentum shift, it is necessary to know the dispersive properties of the 200 MeV transport line. These properties were calculated using the best available knowledge of the currents in the 200 MeV line elements. The calculation predicted a beam width of $\approx$13mm and a height of $\approx$42mm, whereas normal measured values are 12-13mm and 30-34 respectively. The calculation yields for the dispersion values at wire 9:

-2.14m/%
-.157 mr/%

(this calculation used D/A settings for the 200 MeV line elements. A similar calculation using A/D settings gave poor agreement with beam size). The -.06% change in momentum gives +1.3mm or about 70% of the observed shift at wire 9.

The current pulses of S1 and S2 are one-half sine wave with a base length of $\approx$300 μs. At 5 μs from the center, the angular shift of S2 should be .2 mr and a similar number at S1 (amplitude decrease by .9986). Numerically transporting the linac emittance to wire 9 (assuming the above decrease in S1 and S2) showed an angle change of $\approx$.15 mr. A rough estimate using wire 11 data indicates that the observed angle change is $\lesssim$.3 mr.

Conclusion

The observed horizontal shift of the beam at wire 9 appears to be due primarily to the shift of the linac momentum during the same time period. This effect does explain some of the difficulty of keeping a thin septum for large and small betatron oscillations. Matched conditions with an apparent septum thickness of fractions of a mm for efficient multiple turn injection appear rather difficult with the beam center shifting 2mm during the same time period. This further emphasizes the need to achromatize the 200 MeV Line.

The angle change during the period is caused by the droop in the pulsed septums S1 and S2 (a previously known problem). The length of pulse for both of these devices is being lengthened.

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